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Detecting and tracing building occupants to optimize process control

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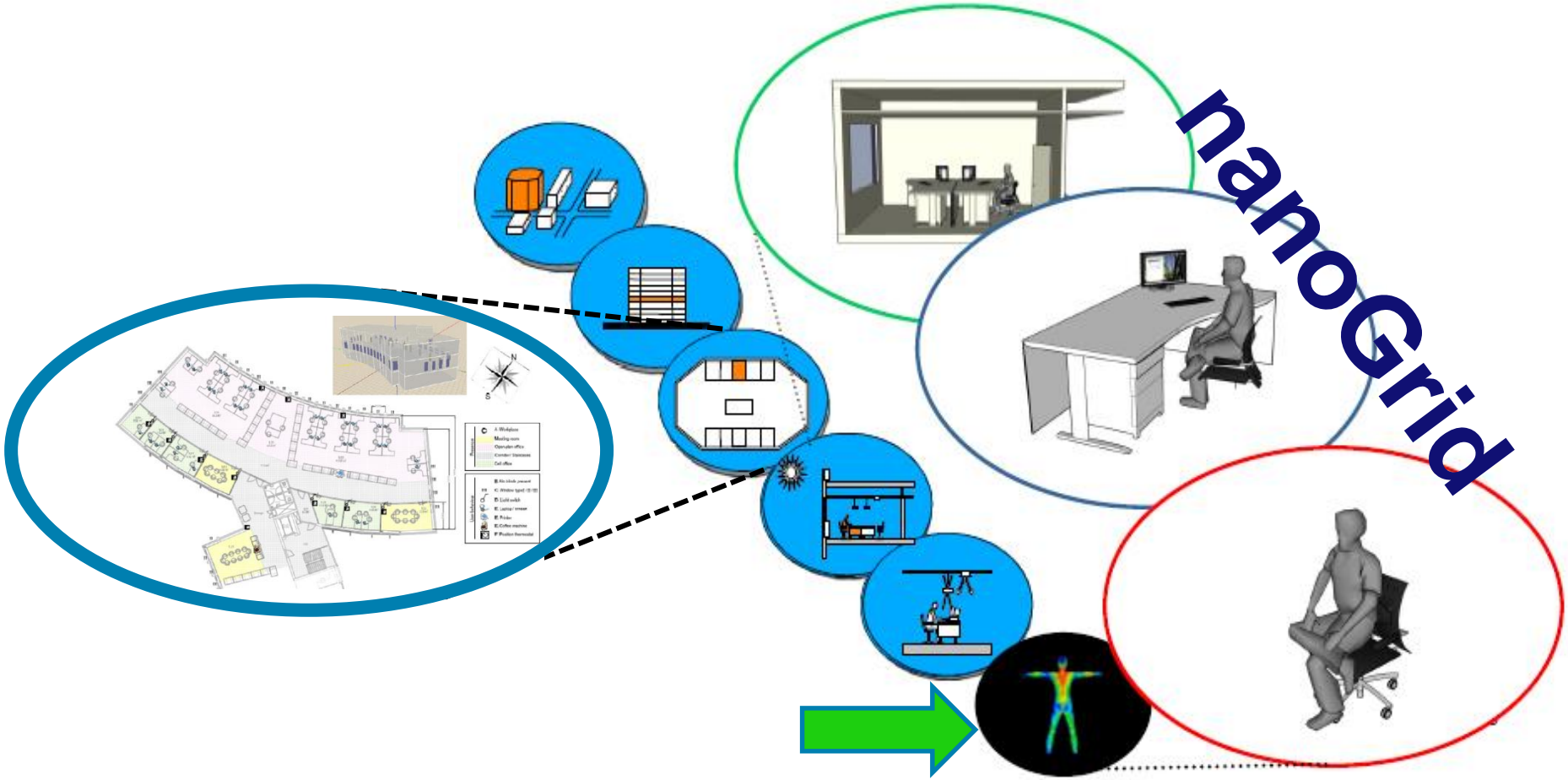
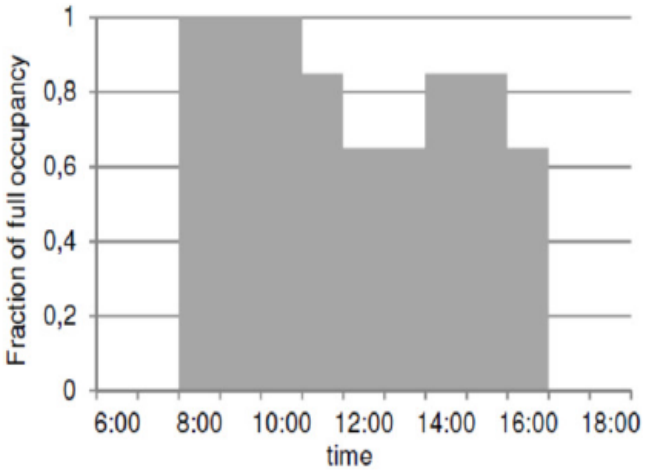
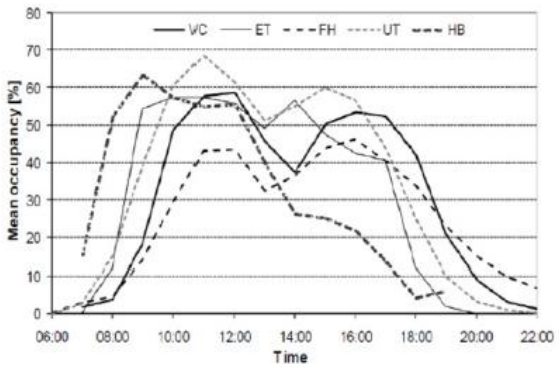
Human in the loop approach



Occupancy profile





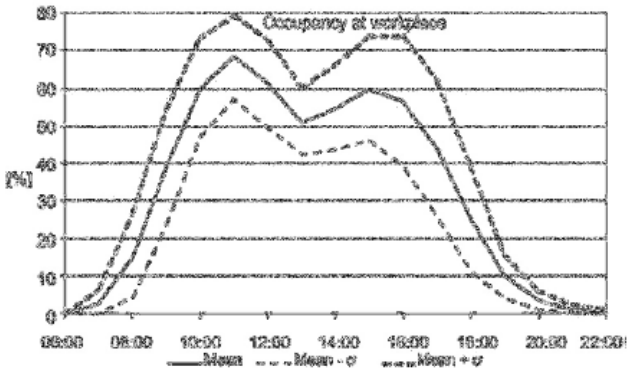
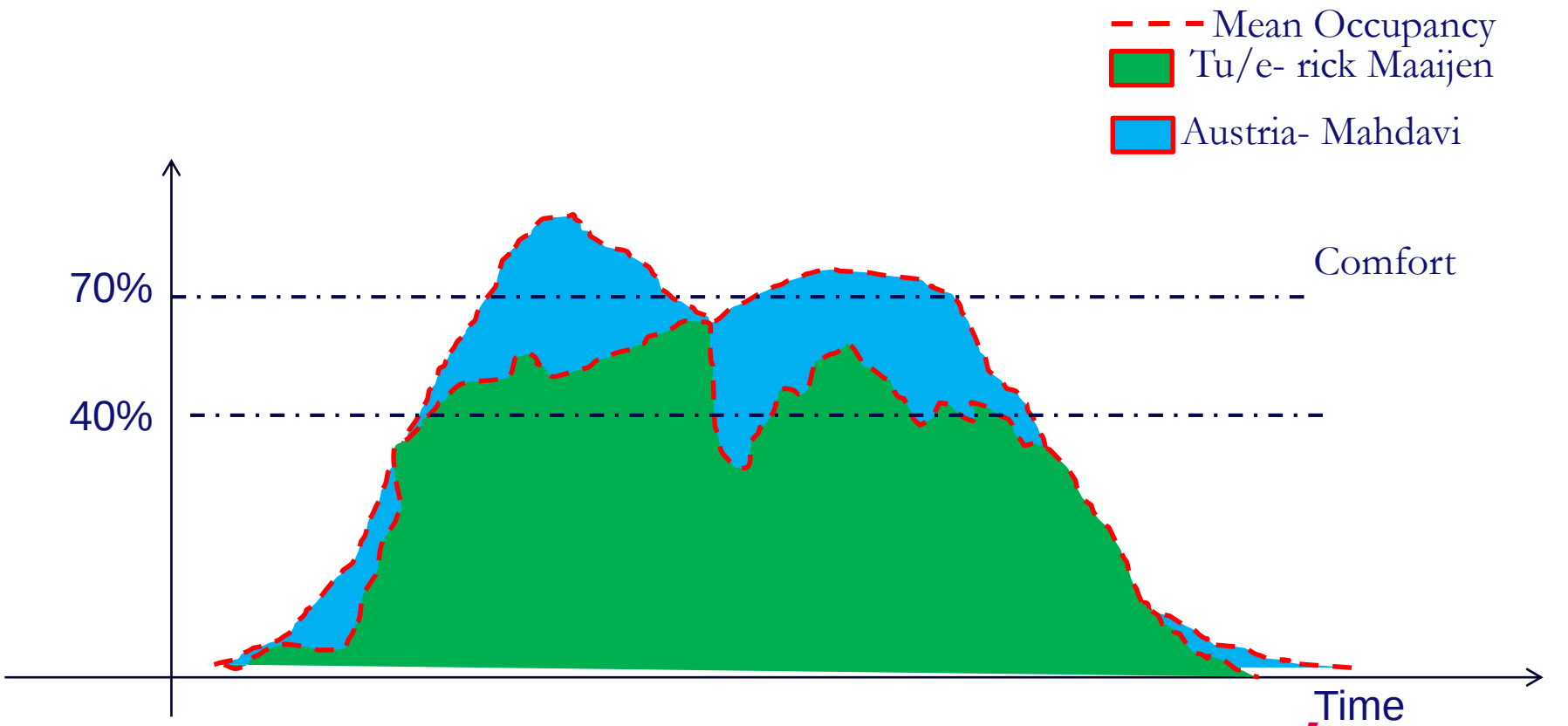


Figure 1 **(I)** Occupancy profile according to the standard EN 15232, modified from (EN 15232), **(II)** Mean occupancy level for a reference day. VC: International organization (Vienna); FH: University (Vienna); ET: Telecom. services (Eisenstadt); UT: Insurance (Vienna); HB: State government (Hartberg) (Mahdavi, 2008) **(III)** Mean occupancy level at workplace and standard deviation for an insurance office Vienna, for 14 months, 89 workplaces, modified from (Mahdavi, 2011)

Drawbacks of Traditional-BEMS

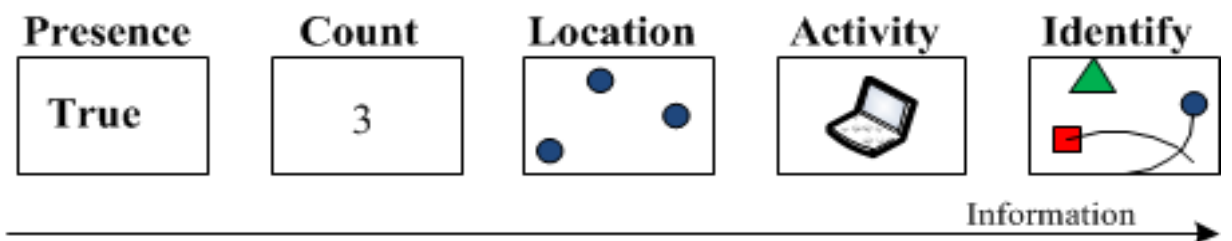
- Operation based on assumed occupancy profiles

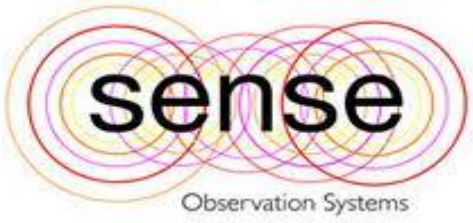


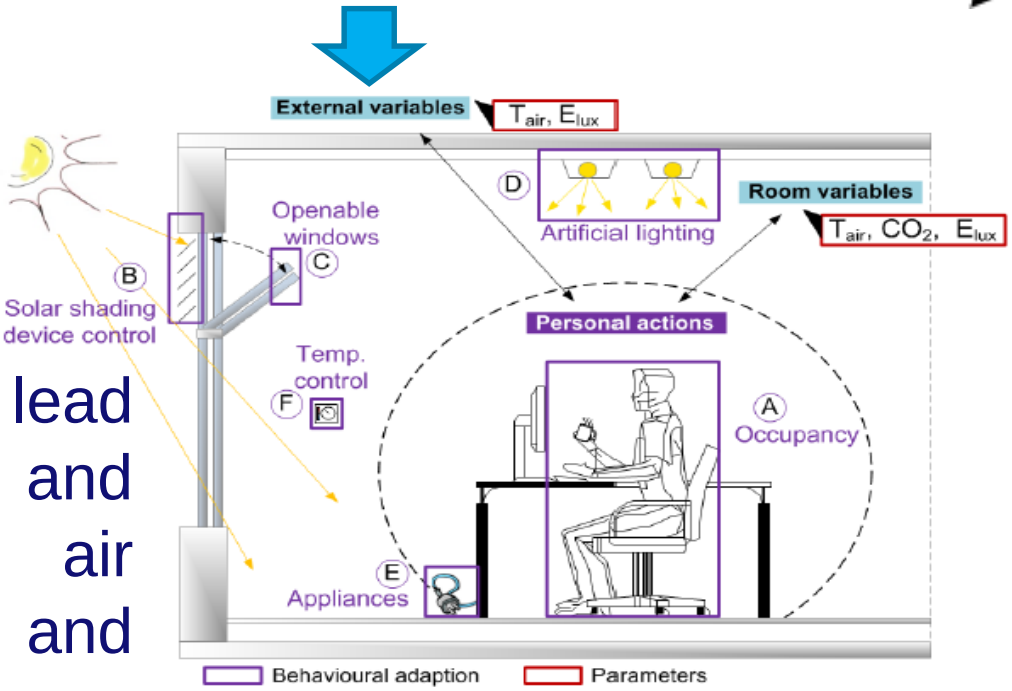
Occupancy and behaviour

Mobile nodes

Fixed nodes



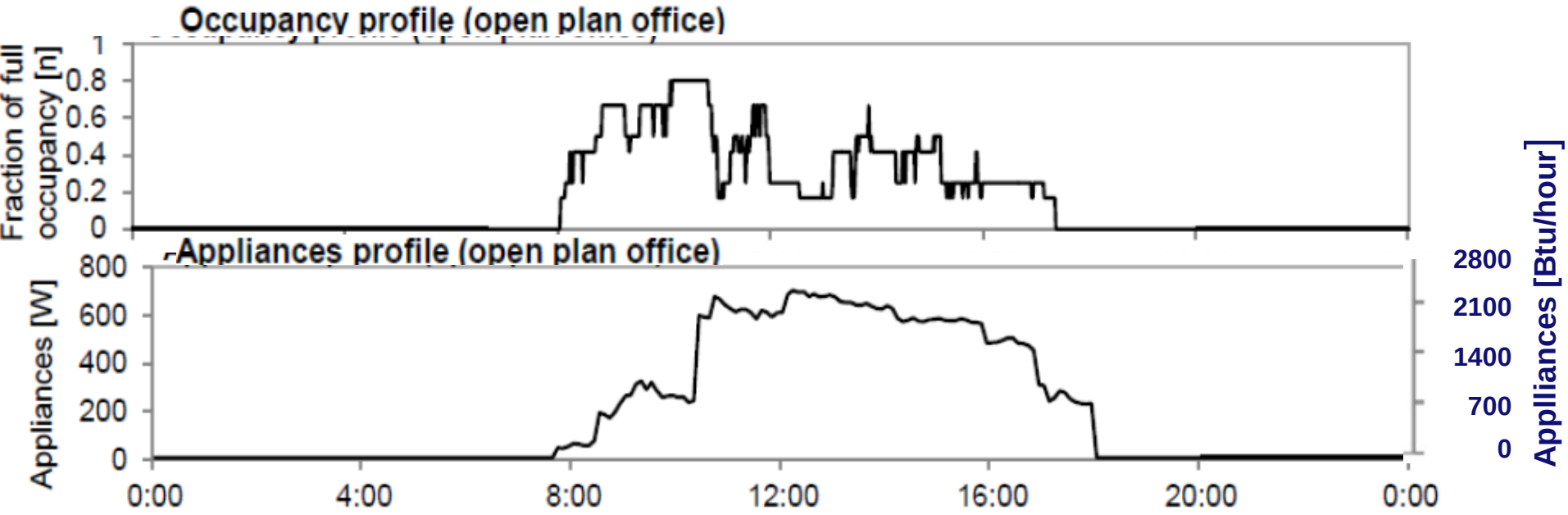




Fine grained information may lead to very fine delivery of lighting and heating, ventilation and air conditioning (HVAC), and visualization of the use of space.

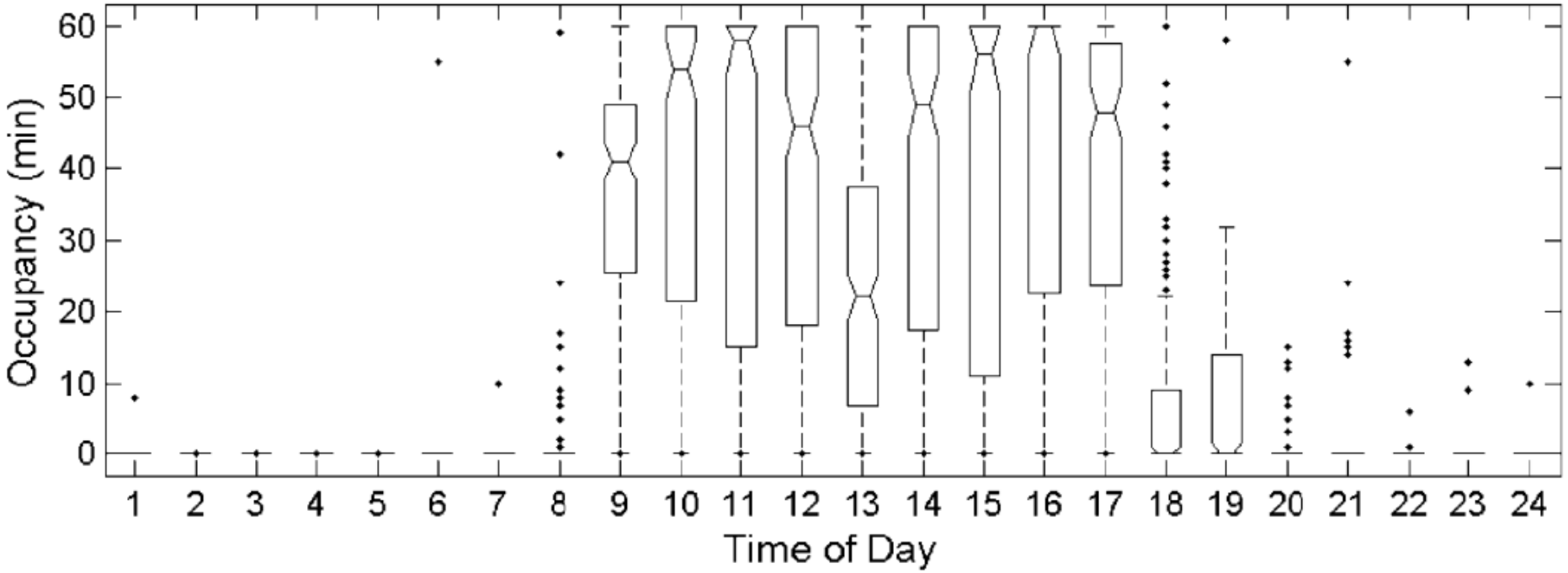
energy savings of between 10- 30% in HVAC loads

Occupancy profile and use of electrical appliances



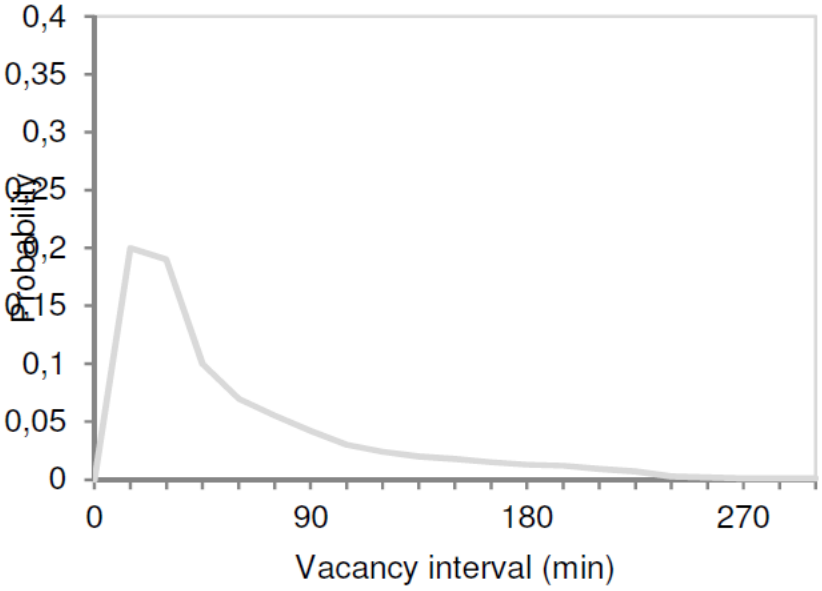
- Measured profiles for occupancy and appliances for a typical winter day

Occupancy profile

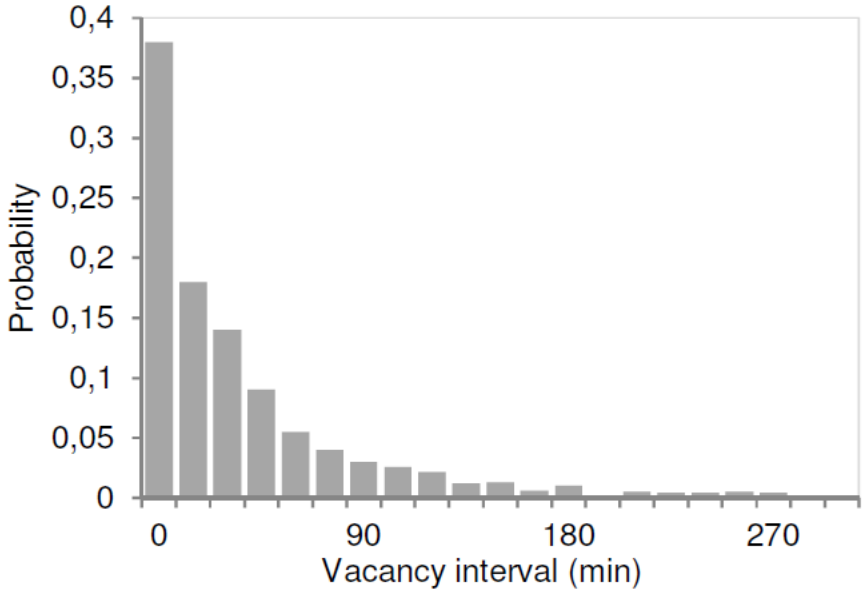


Distribution of hourly occupied time over 24-h of day for an office in San Francisco (Wang et al., 2005)

Occupancy profile



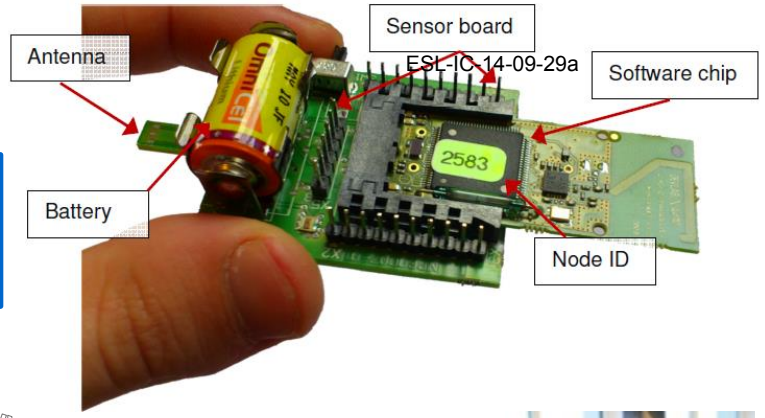
Probability distribution of the vacancy intervals for an office, modified from (Page et al., 2008)

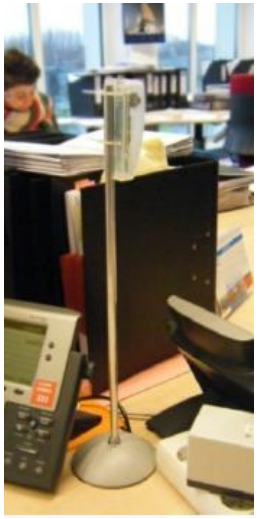


Probability distribution of the vacancy intervals for an office, modified from (Wang et al., 2005)

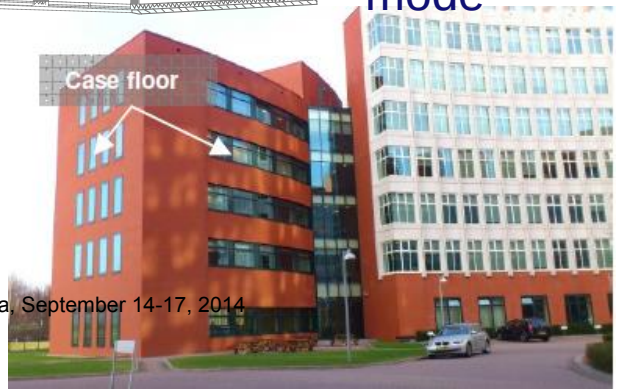
Fixed mode

Flexibele node

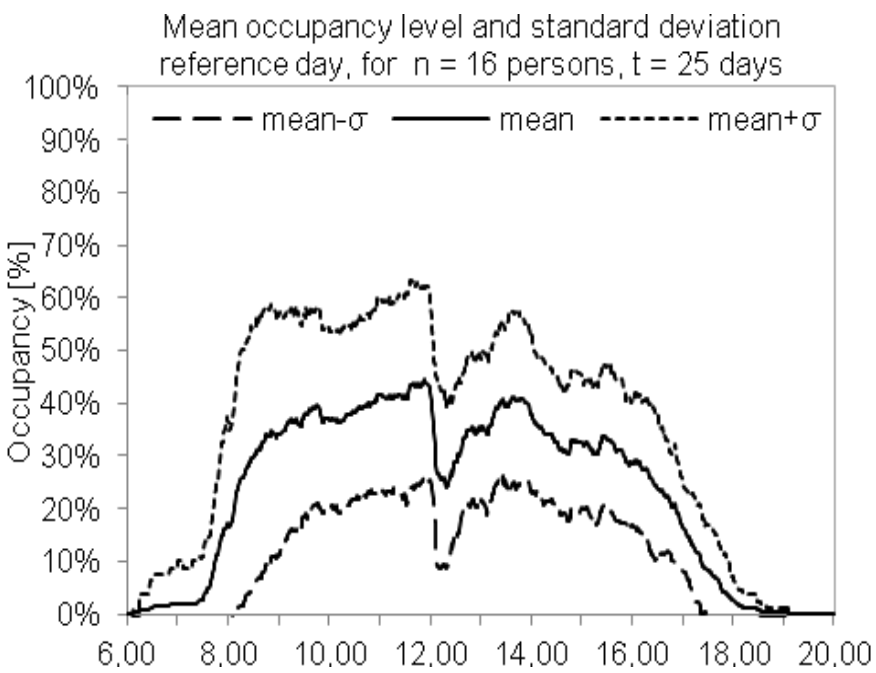


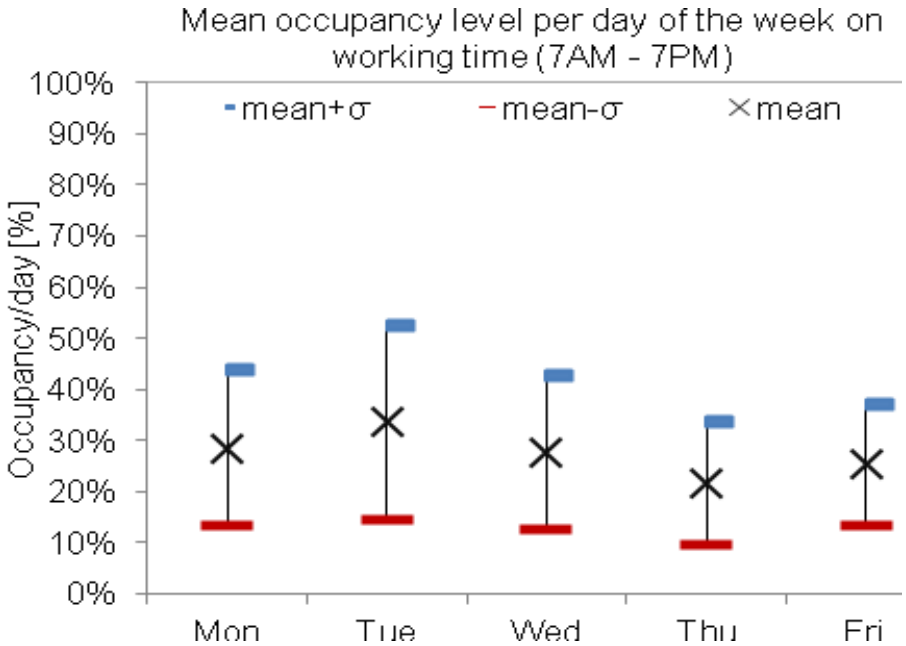


Fixed mode



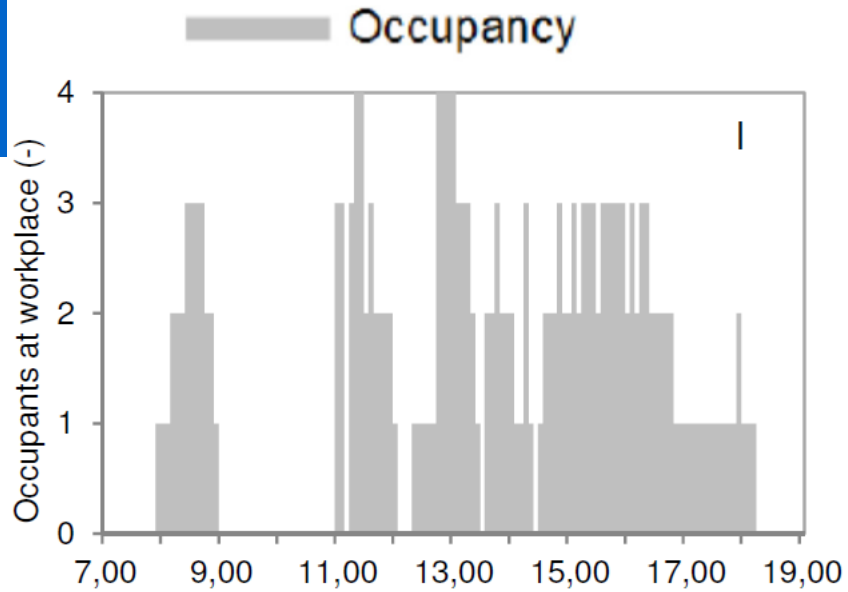
Results occupancy measurements (Maaijen 2012)

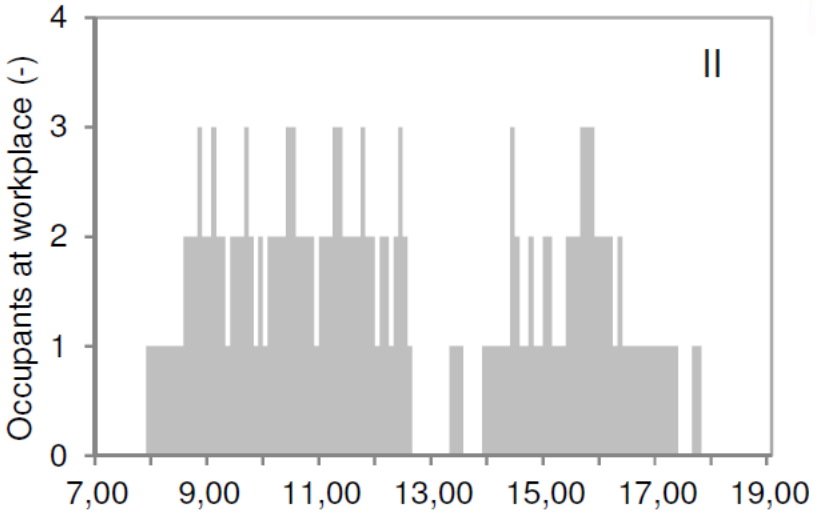




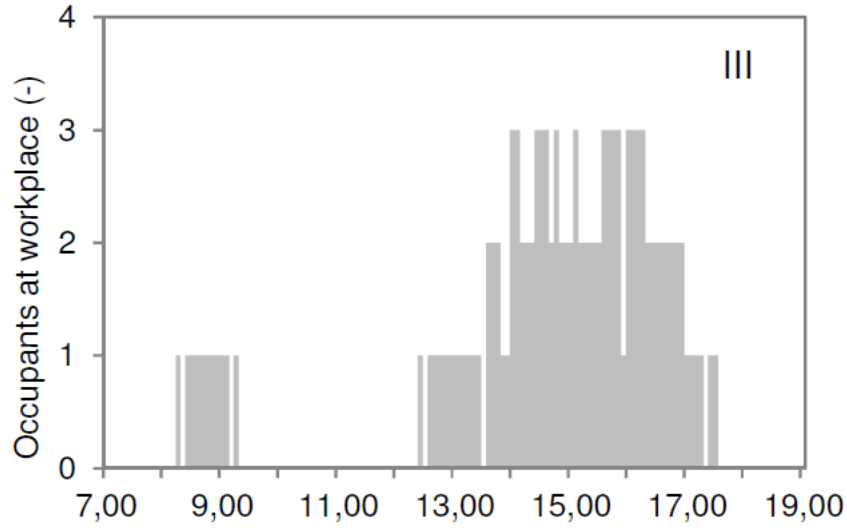
- Mean occupancy level and standard deviation as measured over the six week period
- Mean occupancy level as measured for the different days in a week as a percentage of the maximum occupancy level per person, 7AM – 7PM

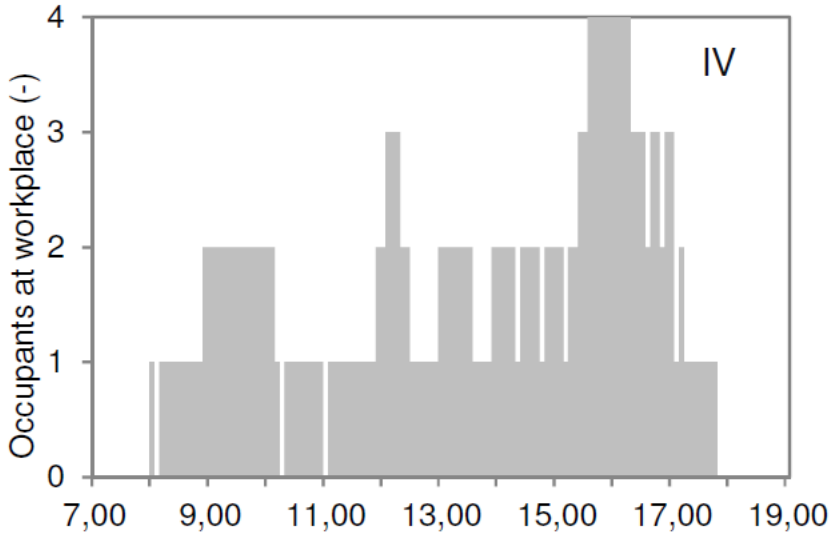
Occupancy profile





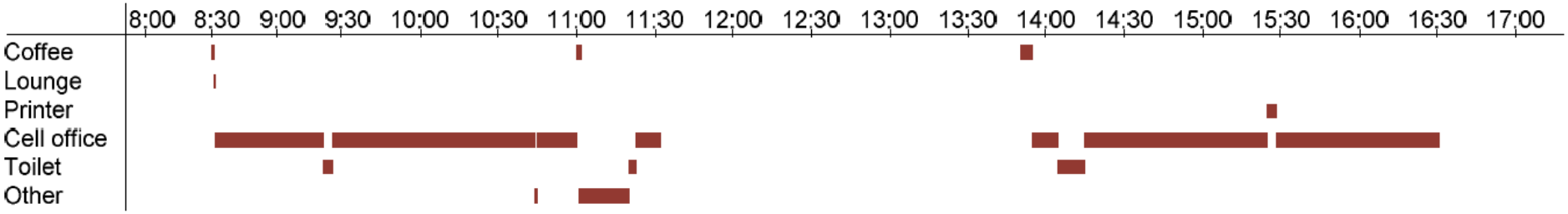
Occupancy of 4 CAD workplaces and electrical load, time step = 5 min, date I and II.



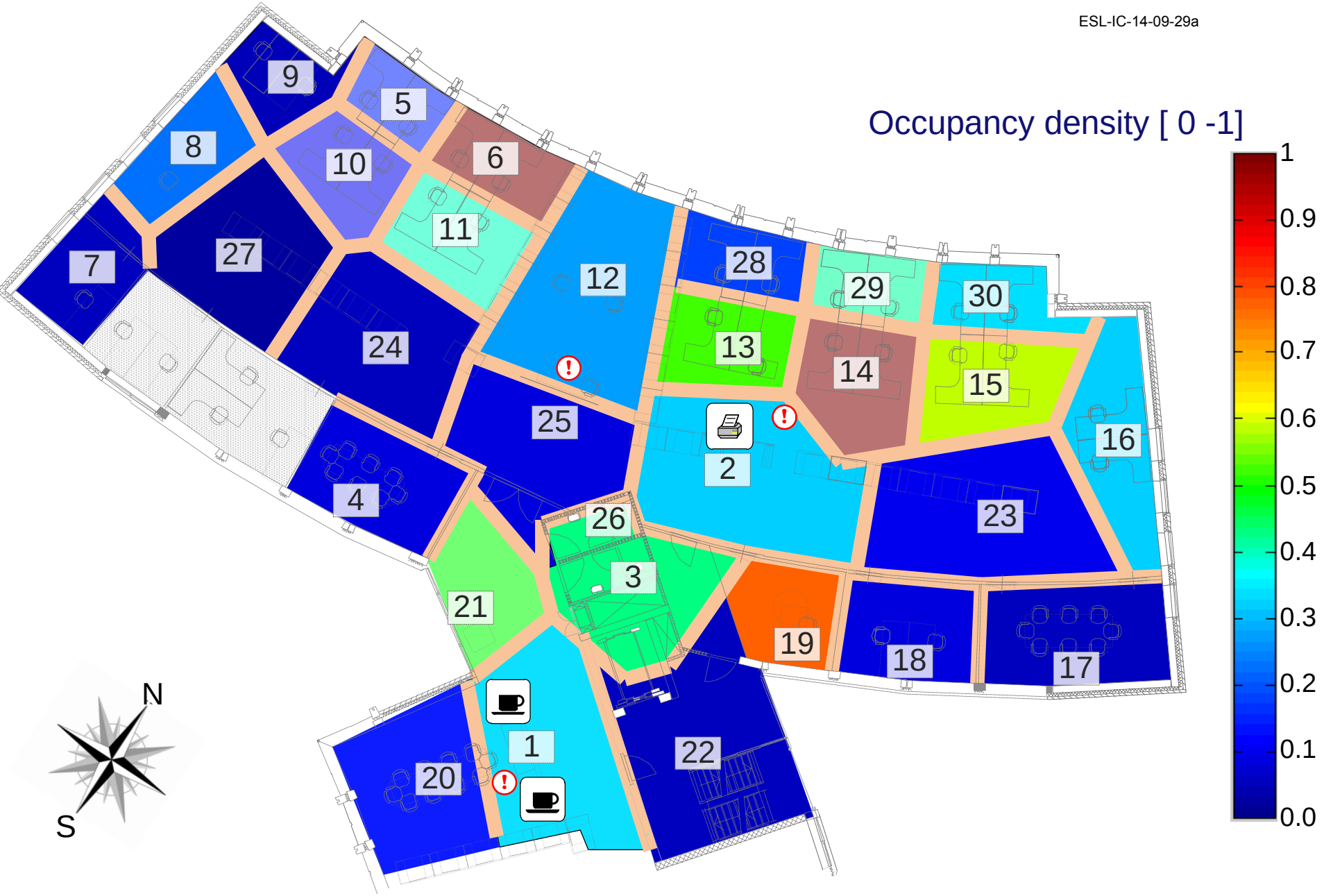


Occupancy of 4 office workplaces time step = 5 min, date III.and IV.

Occupancy profile



Timeline with the position for a reference day of an occupant


Occupancy density [0 -1]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
N
S
1
2
3
4
5
6
7
8
9
10
11
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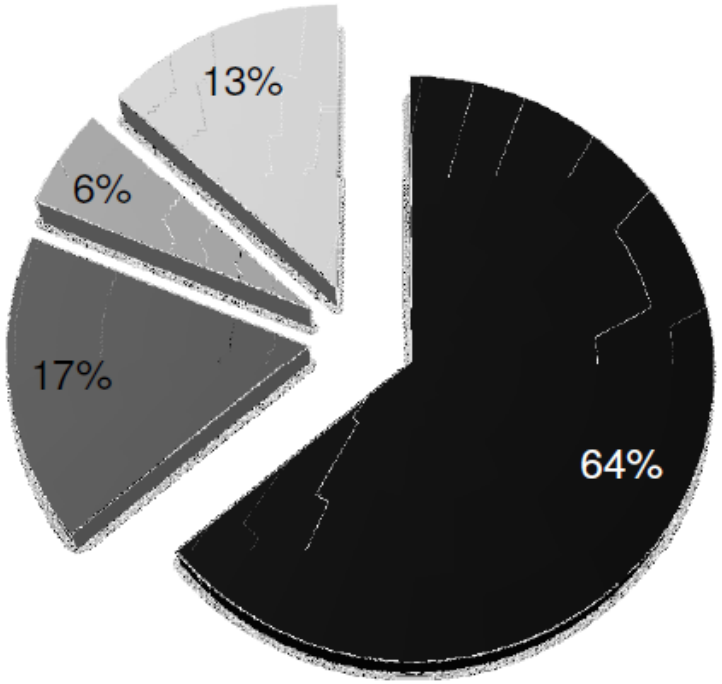
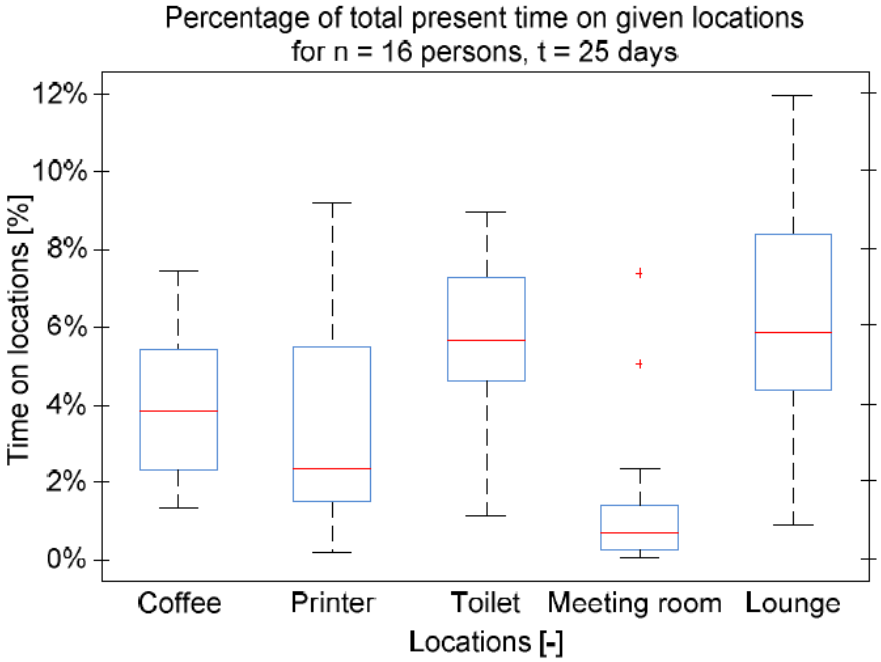
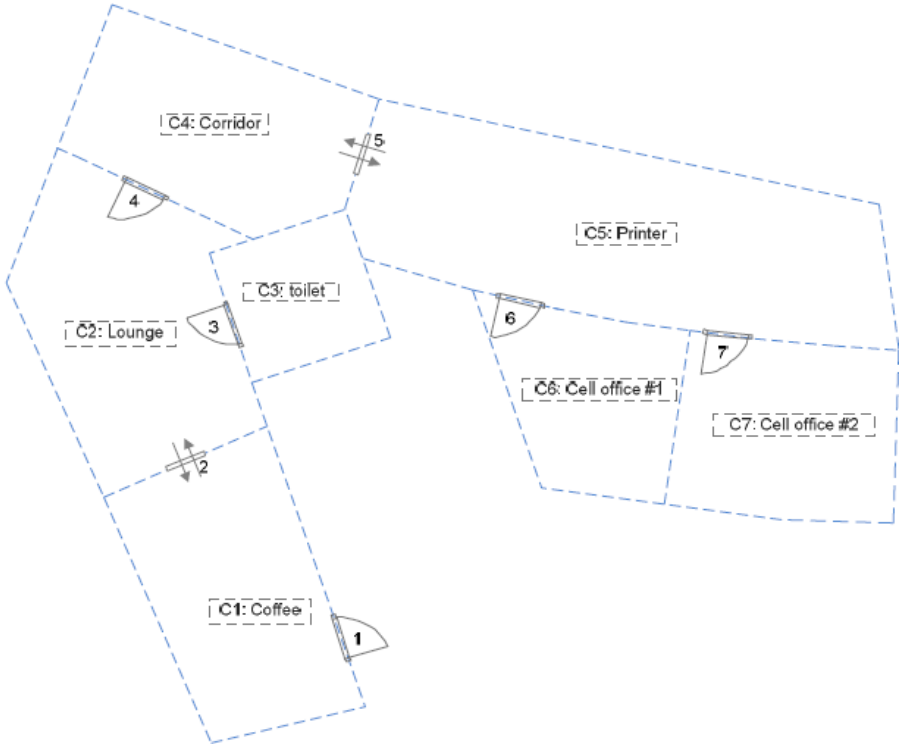




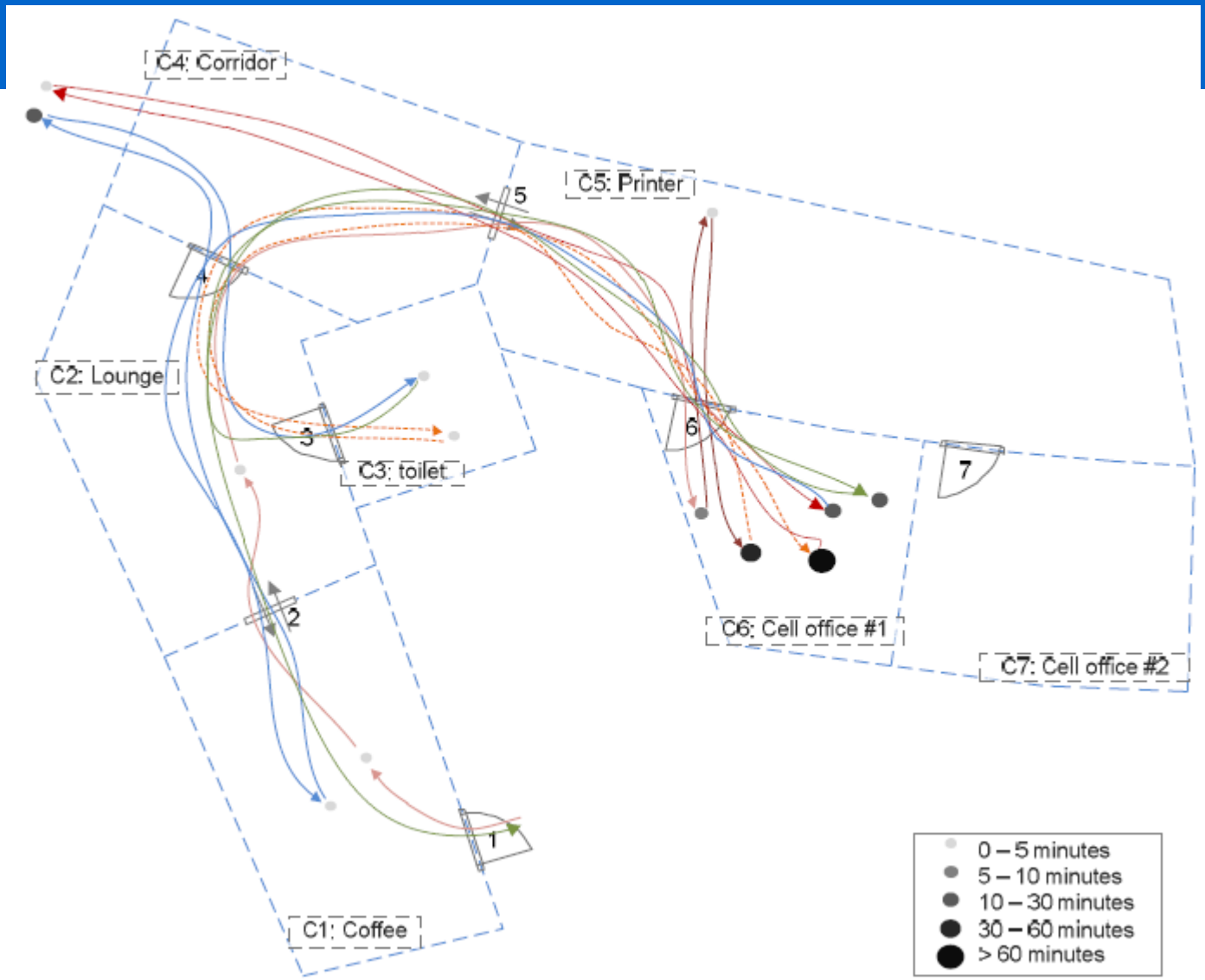
■ Workplace ■ Informal (coffee, lounge, toilet) ■ Workrelated (printer, meetingroom) ■ Other spots

Occupancy profile



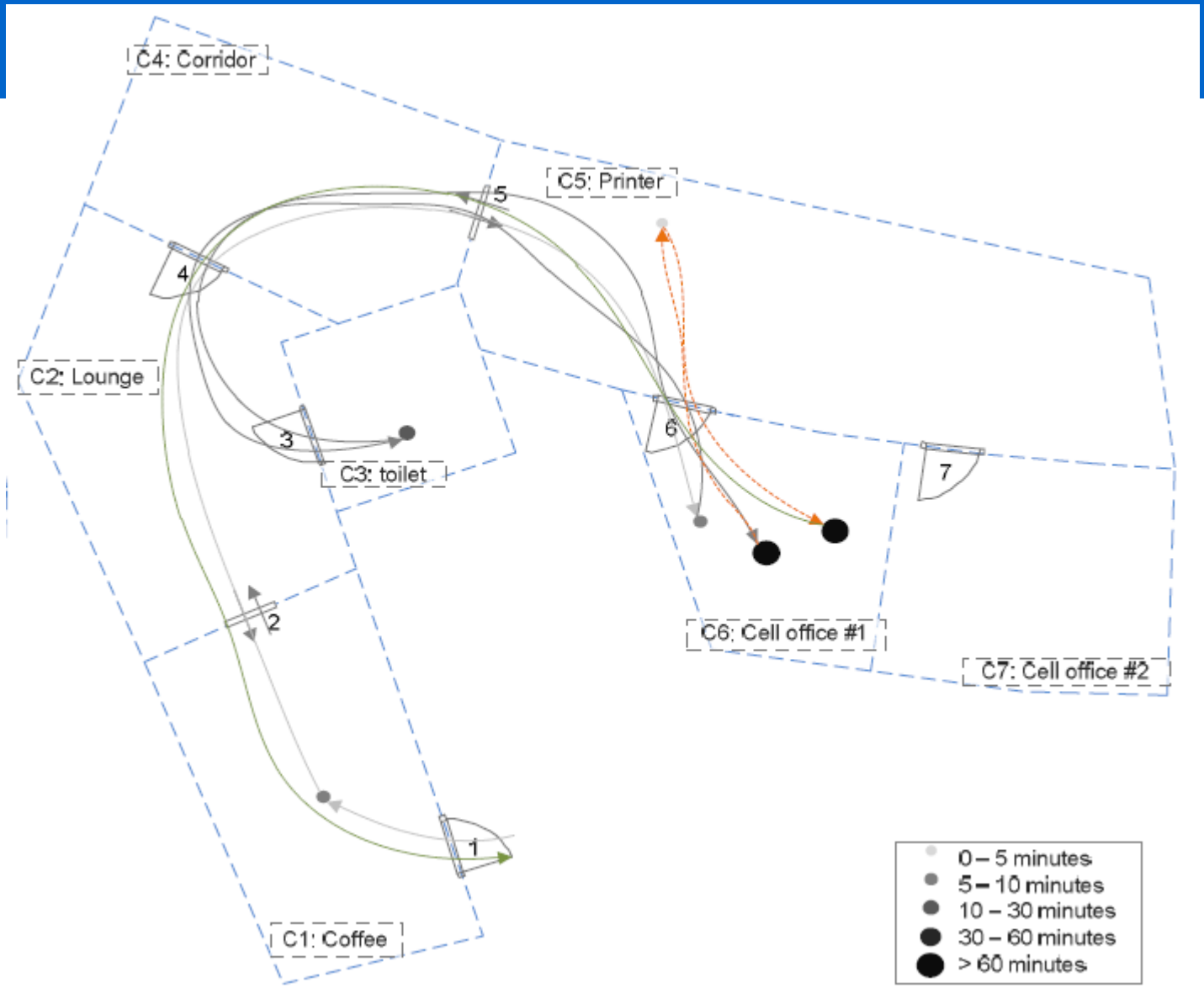
Part of the building model used for modeling, with the coffee machine, lounge, printer and toilet as special spots included in the model.

Occupancy profile



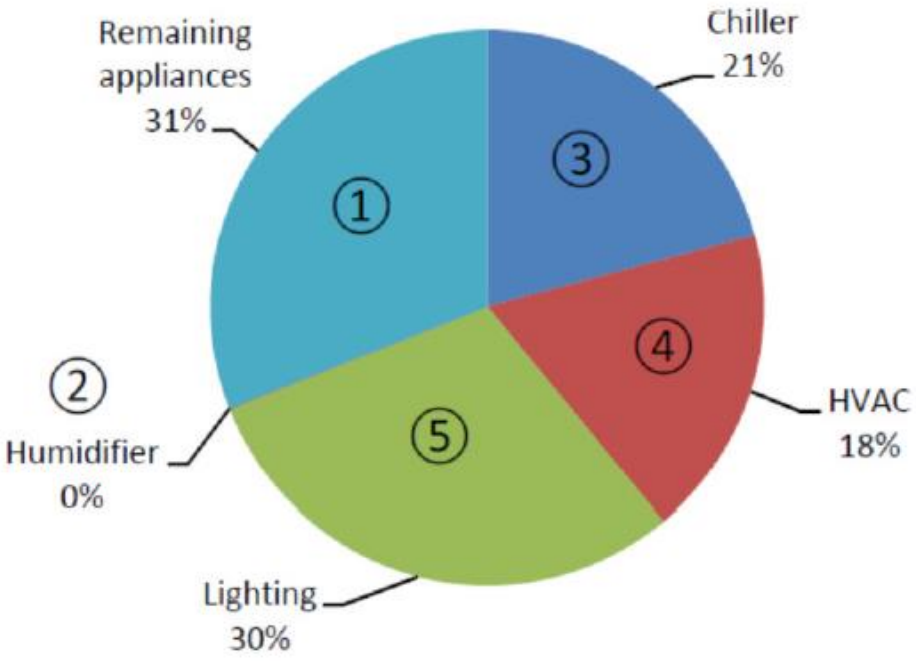
Movement over the floor before leaving the floor

Occupancy profile

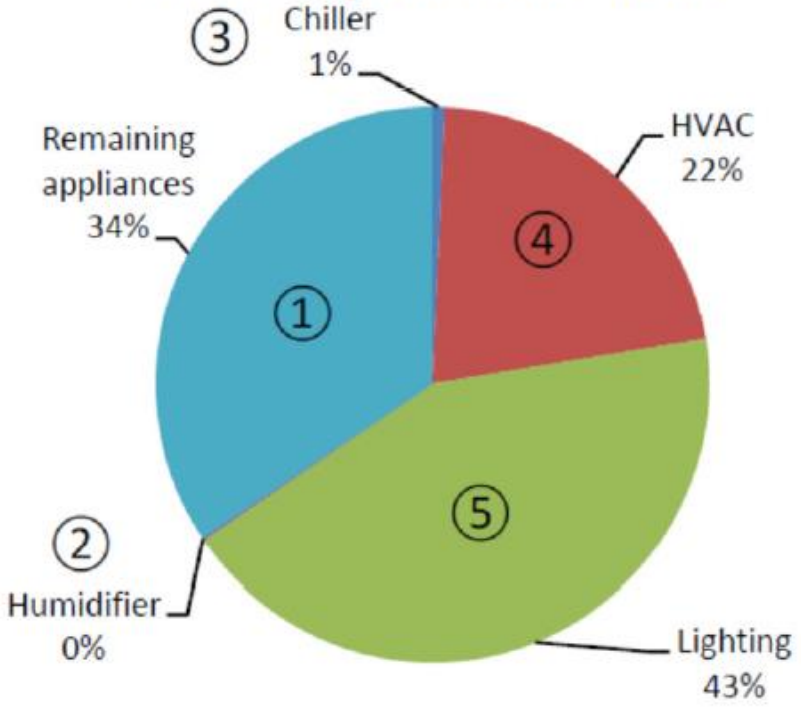


Movement on the floor in the afternoon

Distribution of energy consumption Week 36



Distribution of energy consumption Week 42



Conclusions

Real-time measurement of actual building occupancy was shown through this experiment to represent a fraction of the standard occupancy profile. Despite the sparse and partial floor occupancy, the installed HVAC system remained operational at full capacity resulting in inefficient use of energy, so there is a potential for energy demand reduction.

It is possible to locate the user position, which in principle enables to apply energy to the spots where there is a demand of the building user based on his or her individual comfort. This does not mean that control devices, operable windows, and other adaptive user actions on room or workplace level are superfluous.

Conclusions

As the study by Huizenga et al, (2006) and Hoes et al. (2009) already showed, the ability for a person to control his environment has a significant impact on occupant satisfaction. This asks for a system which combines (i) localizing the building occupant and automatic conditioning of his workplace, and (ii) the possibilities for adjustments of the users' environment.

To apply the individual preferences on the workplace, the human should be included in the loop through controlling his individual comfort level to prevent discomfort and energy consuming behaviour of the occupant to restore his comfort level.

Having the data for occupancy it is still unclear how to present them in the best way to get the maximum insight of them. Especially using the data to track the individual persons is still a challenge which needs more research.

Thank you for your attention!

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